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Effect of Service Technology Upgrade on Dump-Trip Time and Efficiency of Solid Waste Collection In Uyo Metropolis Nigeria

Obot E. Essien[1] , Obioma C. Nnawuihe[2]
[1] *Department of Agricultural and Food Engineering, University of Uyo, Uyo Nigeria. 05003*
[2] *Department of Agricultural and Food Engineering, University of Uyo, Uyo.*

ABSTRACT

The objectives of the time study were: (1) to quantify the dump-trip time of municipal solid waste MSW collection using haul-container system (HCS), as upgrade collection technology, and tipper lorries, previously identified as ineffective, in waste collection in urban route zones of Uyo metropolis; and to evaluate and compare the solid wastes collection efficiencies of both service vehicular technologies to justify selecting upgrade technology of HCS. Time-study survey was effected with 4 HCS trucks and three tipper carriers in 4 out of 6 route zones in Uyo metropolis using snap-back stop watch timing of all on-the-job collection activities and non-job related [loss time] activities. Data were statistically analyzed and inferences made from ANOVA significant differences, coefficient of variance using SPSS version 17 windows. Dump trip time (t_{net}) varied between vehicles and route zones with HCS performing faster and more efficient than tipper lorries in all route zones. Dump trip time varied for between 17 and 27 mins maximum, HCS haulers and between 49 and 59 min maximum for tipper lories, and gave maximum t_{net} ratio of 1 (HCS) : 3.5 (tipper). Average collection efficiencies were 61 – 76% (for HCS pickups) and 59% for tippers. The tipper vehicle consumed longer hours (2.5 – 3.5 times the dump trip time of HCS hauler) to complete about the same waste load collection as the HCS haulers.

KEYWORDS: time study, technology, solid waste, haul container, haul container system, collection efficiency.

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I. INTRODUCTION

The problem of solid waste collection in expanding urban areas is tasking the government money, space and technology challenges. The challenges in the case of expanding municipalities are posed by rapid population increase and the consequent upsurge in the amount of generated solid wastes counterpoised against funds availability and willingness to budget for and dispense concurrently on waste collection disposal as policy - driven action. In the municipality studied, Uyo city population rose above the observed 10 year return value as it rose from 300,000 (1961 census) [1] to 436606 in 2006 (2006 census) [2, 3, 4]. The rise in urban population overflowed into the rural-urban fringe as the urban expanded to accommodate the population surge [5], hence the task of covering the large area in waste collection became a challenge, given that the expected waste load generation rate would have risen also to 20923 tonnes/day [6]. A field survey showed that the volume of generated solid waste in the state increased between 1996 and 1999 at a rate of 0.02 tonnes/capita/year compared to 0.04 and 0.06 tonnes/capita/year for Enugu and Northern states respectively [7,8]. This showed that, on per capita basis, solid wastes indicated even higher values based on projected population. The implication was that the new population was loosening up on the previous rural habit of backyard disposal and were embracing the newly introduced curbside waste collection based on stationary container system using tipper lorries offered by the Government constituted Sanitation Task Force in that period. This surge in volume of waste generation posed a challenge against the system of waste collection. Waste generation (garbage, yard trimming, white goods of old utensil and household discarded equipment, electronics, and kitchen wares (metals, wood or plastic) foams, broken ceiling, amongst others) were taken out from residences and kept unsegregated and unsorted on curbside in front of residence or on kerbs of neighbour roads for house-to-house collection manually by a crew of two or three men into the tipper lorry. At first, when participation was voluntary, things where manageable; the volume of generated wastes was what the few tippers lorries could load off in a day or two; but the sanitation was haphazard. However, when the government intervened with a legally – backed policy of mandatory participation in one day environmental sanitation day, in a month with no vehicular transport (except tippers) and mass human movement, and closing of all markets and offices, and punishable as offence on its breach, then the generated waste load on curbside and road side was high heaps everywhere such that the tippers could not cope to clear off in a day. In some cases the cleared wastes were left uncleared for weeks, a times till another round of mandatory environmental sanitation day on the last Saturday of every month. Tippers, largely were donated voluntarily by Tipper Owners Association (a registered institution) but were fuelled by government Task Force through the Local Governments and State Government fund releases.

The challenge of uncleared waste arose from the voluntary donation of the tippers and volunteer crew, which after the sanitation day were unable to volunteer their vehicles free of charge, and the crews would, of course, not go out on a free labour spree since they were not the employees of the Tippers Owners Association nor Local Government Authorities, nor was the Task force willing and able to vote the bill. Consequently, the objective of the compulsory sanitation exercise was aborted and Environmental Sanitation perished its essence. Collection effectiveness under stationery container and mass generation system was visibly low.

Solid waste management, comprising of all activities which are associated with the gathering of solid wastes and the hauling of wastes, after collection to where the collection vehicle is emptied [9]. Sincero and Sincero [10] considered solid waste management as time-based, multiple-activity operations of collection, transporting and disposal of the generated solid wastes, indicating the technological processes of collection and transportation are sine qua non for environmental management of solid wastes. However, improvement of collection efficiency became a serious urban waste collection problem with tippers. One of the problems of the tippers was the inability to optimize dump trips. Dump trip is time-based activities- componented measure. Generally, most tipper-drivers only wait until their vehicle is completely full, and spilling a times, before they head of the dumpsite to dump their set-out. It is not the most efficient way to handle dump trips [11], especially in the urban routes network. By optimizing dump trips a driver can generally eliminate a trip or two per week for most routes [11]. Turning in and out of circuitous collection routes before getting the lorries full does not reduce the time and fuel the tipper drivers waste idling at urban inter-sections and stop lights [12]. Thus, a different collection system, Haul Container System (HCS), a technology-driven, efficiency-packaged system was needed as an upgrade technology to back out of the difficulties of the tipper lorries in order to meet the health, aesthetic, economics, and efficiency traits of municipal solid wastes collection-to-disposal management. Therefore, trials were made on using the one-hauler per zone per week collection of MSW generated loads in route zones of expanding municipality to replace the low efficiency tipper's stationery container collection system with the following objectives:

1. To carry out time study using HCS pick-up trucks and tipper lorries simultaneously on same route zones.
2. To determine and compare set-out capacity or loading rates, dump trip time, collection efficiency for both HCS pick-up trucks and tipper lorries.

II. METHODOLOGY

2.1 Study Area

The study area, the routes zones and areas were identified; the routes and zones were delineated in the GIS map obtained by using Arc view 3.2 software. The layout is shown in Fig. 1 and Neighbourhood (locality) or community using location were also noted. The study area, which is Uyo metropolis in Akwa Ibom State Nigeria, lies within longitude $7^0 56^1$E and $8^0 20^1$E and latitudes $4^0 50^1$ and $5^0 03^1$N [13]. The study area was designated into six zones, namely zones 1, 2, 3, 4, 5, and 6. A pick up truck was assigned to each zone as in Table 1. The pickup trucks were of the same make and the haul containers, donated by Niger Delta Development Commission (NNDC), were of the same capacity. The HCS used the lift jack system to hook-and-lift containers loading thereby requiring at most 1 assistant for the operator to man the collection, transportation and disposal activities. Correspondingly, tipper lorries were assigned to the same routes zones with the pick-up trucks so that their collection time data would be obtained and compared for the upgrade effect. The study of the effect of upgrading the collection of municipal solid wastes from stationary container system which used the open-back tipper lorries to haul-container system was exercised in the separate zones of the metropolis.

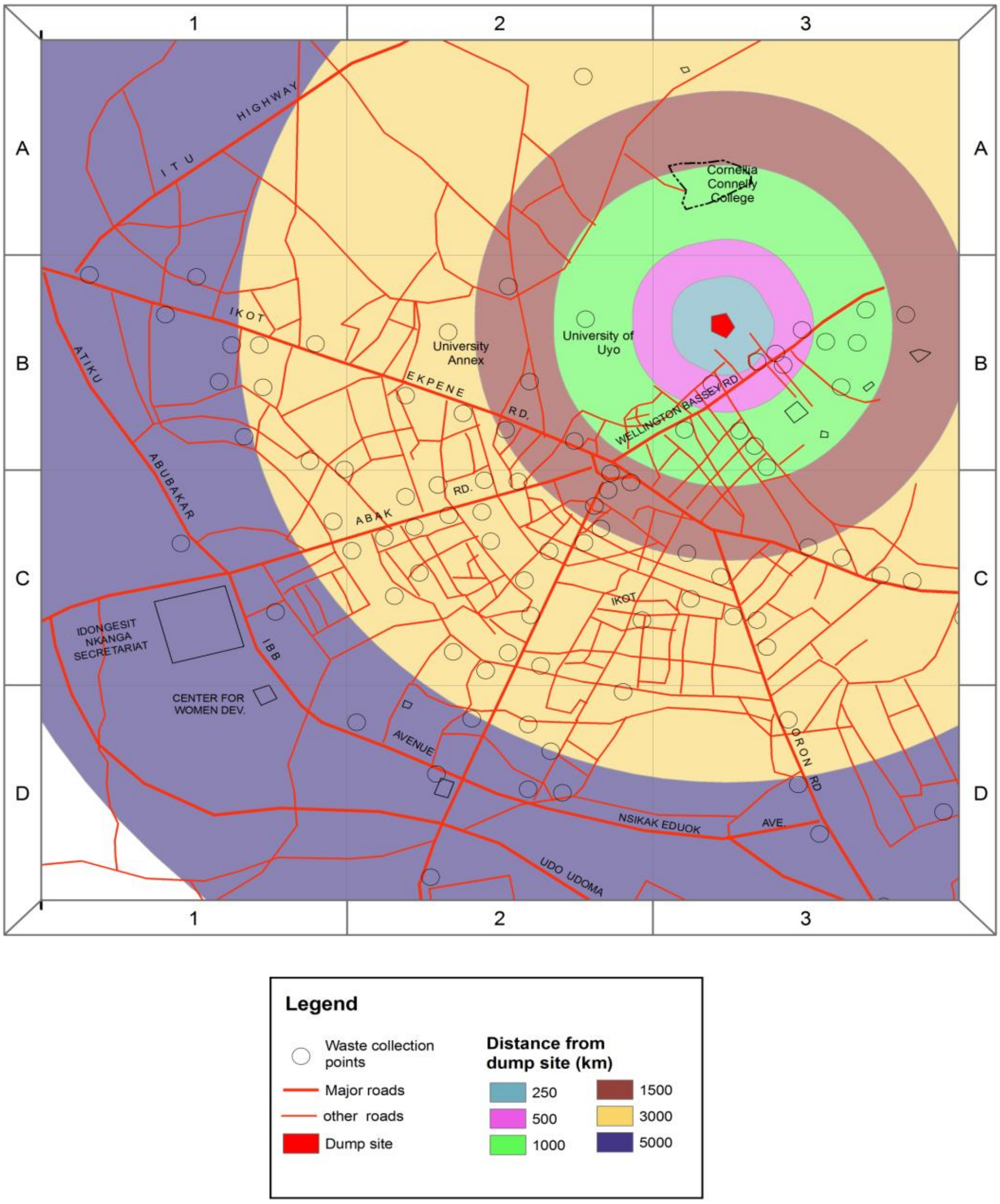

Fig 1. Route zone for solid waste collection in uyo metropolis

Table 1: Assignment of route zones generating area collection truck and tippers lorries for waste collection.

Zone	Area, km^2	Truck	Tipper	No. of Routes in Use
1	*	099	-	23
2	2.00	046	03	19
3	1.00	053	04	16
4	1.00	060	05	16
5				
6	2.25	072	-	18

N/B * truck 099 had a breakdown and was taken out of the competition. These tippers lorries were adequately supervised.

2.2 Measurement of distance and time of activity

Distance from one location to the next were recorded from trucks odometer, previously checked to be in good working condition. All times (time for job-related and non-job related activities) were measured using stop watches by snap-back stop watch method [14]. The designated collection routes zones for both pick trucks and tipper lorries were the same in the same and the number of trips in any zone was pegged at 5 per day for adequate monitoring (Table 1). The trucks took off with no container from the same point - the dumpsite (which was used as the dispatch time) to the first station in time $\mathbf{t_1}$.

2.3 Cycle Time for Haul container system activities

Pick-up truck mounted the first loaded container on its truck in time $\mathbf{m_1}$ and carted it away to the disposal site in time $\mathbf{h_1}$. It unhitched the container at the disposal station in **s** min mounted back the empty container in **u min** before moving back in time $\mathbf{h_2}$ to the first container station. Again the empty container dropped was in time $\mathbf{m_2}$ at the first container station, before the truck moved to the next container station in time **dl** to start another trip cycle till it reached the last station to carry out the last trip for the day. Thereafter, the pick-up went back to the dispatch station without a container to wait for the next day exercise. The time losses in between these activities and the time taken at any activity station were measured with the same snap-back stop watch. The total activities time was the sum of activity times for components activities. Thus the cycle time (t_{net}) or the time for 1 trip was [10, 15]

$$T_{net} = m_1+h_1+u+s+h_2+m_2+d_l \qquad (1)$$

With component activities by HCS pick-up truck as follows:

T_{net} = allowable cycle time

$\mathbf{m_1, m_2}$ = time taken to mount loaded container and unloaded container at container (community waste bin) location respectively.

$\mathbf{h_1, h_2}$ = time taken to move loaded container to disposal and return empty to container station.

$\boldsymbol{u, s}$ = time taken unmount container for pick-up truck at disposal site and mount back empty container at the same site respectively.

$\boldsymbol{dl}$ = time for inter-station transit.

2.4 Cycle time (t_{net}) for waste collection by tipper lorries

The time regime for waste collection by tipper lorries was of the stationary container system. The tipper got to its first station unloaded and the 2-3 men crew scooped into its tray the unorganised and uncompacted solid wastes in time in or picked any bagged wastes or waste bins in time **m**, then moved to the next stationery container in time **dl** to load. It proceeded to the next stations until the tipper tray was full before it drove off to the dumpsite in time h_1 to off-load its solid waste content.

There was no mounting and dismounting of containers in tipper's operation as in HCS. Therefore, the average cycle time, t_{net} was [10, 15]; $t_{net} \sum_{i=1}^{i=n}(m_i + dl_i)c_l + s + h$

$$\text{Or, } t_{net} = \sum_{i=1}^{n} m_i c_{l+} \sum_{c=1}^{n} dl_1 c_{l-i} + s + h \qquad (2)$$

Where m_i = time taken to load (scoop) unorganized solid wastes into tipper tray at collection station

dl_i = time taken by tipper to move to the next collection station

c_l = Number of collection stations

s = time taken to off-load waste at disposal station

h = time taken to drive from collection station to disposal station. All times are in minutes.

2.5 Set out Capacity

The volume capacity of pick-up truck was the volume of the ridged-roofed-covered container of dimension 2.25m x 1.22m x 1.48m for length, width and height respectively or $4.1m^3$ overall. The volume of the tipper wagon was 4.95m x 2.29m x 0.6m for length, width, and height respectively or $6.8m^3$ i.e. 1.7 times the capacity of the pick-up truck.

III. RESULTS AND DISCUSSION

The results of the field measurements of travel time components and dump trip time for municipal solid waste collection in Uyo metropolis by HCS pick-up trucks, as upgrade service technology, and tipper lorries, as the previous service technology, were collated and are given in tables below. Table 2 gives for different vehicular grades (HCS pick-up trucks and tipper lorries and the statistical summary of the average net travel times **(t_{net})** used on (1) and their variations **(Cv),** while Table 3 gives significant differences for and between the trucks and tippers. Data from only two tipper lorries were used for analysis as the third tipper could not complete the test.

3.1 Average daily dump trip times, t_{net}

The average daily dump trip times for each vehicular grade showed distinct variability (Table 2). For the pickup trucks, 060 had high variation only in the first week (**Cv** = 19%) (Table 2), 053 had significant variation in week 2 (**Cv** = 30.43%), truck 046 had the highest variation with **Cv** = 23% in week 4. Otherwise the variations within $\mathbf{t_{net}}$ of each vehicle were not significant (Table 3). However, Table 2 shows that the highest variation between daily trip times was obtained by truck 046. Truck 072 had no significant variation.

The four trucks showed significant differences ($p<0.001$) between their trip times **(t_{net}).** The between-group variance was highly influential on the $\mathbf{t_{net}}$ than their within-group errors (Table 3), showing that the significant difference depended on $\mathbf{t_{net}}$ variance between the trucks (i.e. truck performance) [16]. For the tipper lorries, the t_{net} values were very high, giving ratio of $\mathbf{t_{net}}$ (truck) to $\mathbf{t_{net}}$ (tipper) ranging from 1:2.5 (average) to 1:3.5 (maximum) (Table 4).

The tipper's dump-trip times also varied both between the tipper's t_{net} and also within the time of each tipper lorry such that **Cv**=36% for tipper 04 and 33% for tipper 05 (Table 2). However, ANOVA showed that variances were significantly different at $p<0.1$, but not at $p=.05$. Maximum $\mathbf{t_{net}}$ and minimum $\mathbf{t_{net}}$ were recorded by tipper lorries and truck 072 respectively (Table 2). The overall average $\mathbf{t_{net}}$ for both the trucks and the tipper lorries are shown in Table 2, giving overall $\mathbf{t_{net}}$ as 23.50 min. for truck 046, 24.22 (the highest time) for 053, 23.83 min. for 060, and 17.30 min (the least time) for 072; also overall t_{net}=59.18 min. for tipper 04 and 49.75 min for tipper 05.

For the pick-up truck, dump trip time (or net cycle time **t_{net})** showed significant differences at $p<0.001$ between net trip times of the three trucks (046,053,060) with higher $\mathbf{t_{nets}}$ and truck 072 with the least $\mathbf{t_{net}}$ (Table 2).

3.1.1 Overall mean dump trip time: The overall mean dump trip times (Tables 2) were different for the trucks, being 23.50 $\pm$ 4.55 min for truck 046, 24.21 $\pm$ 3.72 min for truck 053 (which time was the highest), 23.83 $\pm$ 2.81 min for truck 060, and 17.30 $\pm$ 1.97 min for truck 072 which dump trip was the least time. The **Se** for dump time for truck 046 was 4.55 min with a **Cv** = 19% showing the greatest variation from the overall average $\mathbf{t_{net}}$ compared to **Cvs** of 15%, 12%, and 11% t_{nets} of for trucks 053, 060 and 072 (Table 2); consequently, the variation between the components of $\mathbf{t_{net}}$ for 046, which was very significant at $P < 0.001$, was the major cause of variation between the overall t_{nets} of the group of 4 trucks (046, 053, 060, and 072). Comparing the least t_{net} (17.30 min) of truck 072 with those of other trucks (060, 046, 053), using Waller Duncan parameter, a significant difference was observed at $p = .05$. For the tipper lorries, the overall dump trip times (t_{net}) (Table 2) showed significant difference between them only at $p = 0.1$, but were not significantly different at $p = .05$. The overall dump trip times were 59.18 $\pm$ 5.09 min with Cv = 32% for tipper 04 and 49.74 $\pm$ 9.81 with **Cv** = 34% for tipper 05, other wise there were no significant differences within t_{net} of each tipper in the 5 trips of each day monitored. Comparing average t_{net} of the trucks with t_{net} of the tippers, a significant difference was observed at $p = .05$. In summary significant temporal variation ($p< 0.01$) existed between mean dump trip times (t_{net}) of pick-up trucks and tippers in MSW collection in the route zones in Uyo metropolis.

3.2 The t_{net} ratio

The significant difference between t_{net} of tipper lorries and pick-up trucks also played up in the t_{net} ratio. The t_{net} ratio is the quotient of maximum t_{net} (tipper) to maximum t_{net} (trucks). Actually in Table 4, minimum t_{net} tipper to minimum t_{net} pick-up truck turned out to give a higher value of t_{net} ratio while the ratio of maximum t_{net} tipper to maximum t_{net} truck turned out with a lower value of t_{net} ratio, the values used were weekly average of daily trip t_{net} .The maximum ratio varied in average t_{net} value from 2.3 – 3.5, while the minimum t_{net} ratio was more homogeneous, varying from 2.0 – 2.5 only. In general t_{net} ratio varied between 2.0 and 3.5. To create homogeneity in t_{net} ratio, then the route designs should be calculated to ensure that the dump trip time for all trucks in all routes do not significantly differ. Hence more research is needed in route re-design.

Table 2. Average Dump trip time (t_{net}) for collection-to-disposal of municipal Solid waste in Uyo by HCS trucks and tipper lorries

Trip 1	HCS pick-up trucks				Tipper lorries	
	046	053	060	072	04	05
M	24.6	24.3	24.8	18	32	41.5
T	29.4	24.3	29.4	19.3	76.5	31.9
w	29.9	26.3	25.4	16.5	79.5	37.1
t	27.4		20.4	23.1		
f	25.4		18.2	19.4		
Ave	**27.34**	**24.97**	**23.64**	**19.26**	**62.67**	**36.83**
Sd	**2.35**	**1.15**	**4.41**	**2.45**	**26.67**	**4.81**
Cv	**8.59**	**4.62**	**18.65**	**12.71**	**42.45**	**13.05**
Trip 2						
m	21.2	23.4	29.4	14.8	79.3	36.8
t	24.3	21.3	23.4	16.3	82.3	79.3
w	21.4	36.5	24.5	17.1	32	37.6
t	22.3		24.3	17.3		
f	29.6		24.4	16.		
Ave	**23.76**	**27.07**	**25.20**	**16.30**	**64.53**	**51.23**
Sd	**3.49**	**8.24**	**2.39**	**1.00**	**28.21**	**24.31**
Cv	**14.68**	**30.43**	**9.48**	**6.12**	**43.72**	**47.45**
Trip 3						
m	24.6	23.4	23	17.6	57.2	58.5
t	29.4	23.4	23.3	17.2	59.5	76.5
w	26.9	26.5	25	16.4	37.1	41.5
t	27.4		25.1	16.3		
f	25.4		23.2	19.1		
Ave	**26.74**	**24.43**	**23.92**	**17.32**	**51.27**	**58.83**
Sd	**1.86**	**1.79**	**1.04**	**1.13**	**12.32**	**17.50**
Cv	**6.97**	**7.33**	**4.34**	**6.55**	**24.04**	**29.75**
Trip 4						
m	18.8	24.6	25.4	14.3	58.3	59
t	13.1	23.6	27.1	16.4	76.5	79.5
w	13.2	22.1	23.1	18.6	41.5	41.5
t	17.6	22.1	25.1	16		
f	22.3		21.4	19.5		
Ave	**17.00**	**23.10**	**24.42**	**16.96**	**58.77**	**59.00**
Sd	**3.92**	**1.22**	**2.21**	**2.09**	**17.50**	**17.50**
Cv	**23.04**	**5.30**	**9.03**	**12.32**	**29.79**	**29.66**
Trip 5						
m	24.3	20.6	24.4	15.3	59	59
t	21.2	20.5	17.5	15.4	79.5	31.9
w	21.4	24.5	23.5	16.3	37.5	37.6
t	22.7		24.3	16.2		
f	24.1		20.2	20.2		
Ave	**22.66**	**21.87**	**21.98**	**16.68**	**58.67**	**42.83**
Sd	**1.55**	**2.28**	**3.03**	**2.02**	**21.00**	**14.29**
Cv	**6.88**	**10.43**	**13.80**	**12.11**	**35.80**	**33.36**
Overall Average						
Ave.	**23.50**	**24.21**	**23.83**	**17.30**	**59.18**	**49.75**
Sd	**4.55**	**3.72**	**2.81**	**1.97**	**19.12**	**16.94**
Cv	**19.36**	**15.36**	**11.79**	**11.41**	**32.31**	**34.05**

Table 3: ANOVA of dump trip times of trucks and tippers

	Sum of Squares	df	Mean Square	f	Sig.	Sign. Diff.
046 Between Groups Within Groups Total	341. 332 155.628 496.960	4 20 24	85.333 7.781	10.966	.000	Trip time for 1-5 are significantly different at P = 0.01
053 Between Groups Within Groups Total	47.751 159.667 207.418	4 11 15	11.938 14.515	.822	.537	Ns between trips 1-5
060 Between Groups Within Groups Total	28.458 161.096 189.554	4 20 24	7.115 8.055	.883	.492	Ns between trips 1-5
072 Between Groups Within Groups Total	26.710 66.860 93.570	4 20 24	6.677 3.343	1.997	.134	Ns between trips 1-5
04 Between Groups Within Groups Total	311.611 4805.973 5117.584	4 10 14	77.903 480.597	.162	.953	Ns between trips 1-5
05 Between Groups Within Groups Total	1154.851 2861.567 4016.417	4 10 14	288.713 286.157	1.009	.448	Ns between trips 1-5

N/B: Ns = not significant

Table 4: t_{net} ratio (t_{net} tipper/t_{net} truck)

Avg. weekly Trip	t_{net} tipper max.	t_{net} tipper min.	t_{net} truck max	t_{net} truck min	tnet ratio max	tnet ratio min
Trip 1	62.67	36.83	27.34	19.26	2.3	2.0
Trip 2	64.53	51.23	27.02	16.03	3.1	2.4
Trip 3	58.83	51.27	26.74	17.32	2.9	2.4
Trip 4	59.00	58.77	24.42	16.96	3.5	2.4
Trip 5	58.67	42.83	22.66	16.68	2.6	2.5
Overall	58.18	49.75	24.21	17.30	2.9	2.5

N/B: t_{net} are from table 2. t_{net} ratio = t_{net} tipper/t_{net} truck, max t_{net} ratio = max tipper t_{net}/ max truck t_{net}

3.3 Effect of Technology Upgrade on cycle time and disposal rate.

3.3.1 Cycle Time, t_{net}: The cycle time for trips varied between the trucks, hence root zones, and between the trucks and tippers (Table 2), hence grade of service technology application. The overall average cycle times (Table 2) for pick-up trucks were in the order 24.21 for 053>23.83> for 060>23.50 > for 046>17.30 for 072 min and for the tippers were 59.18 > 49.75 min for tippers 04 and 05 respectively (Table 2). This means that the service of collecting municipal solid waste in the municipality with the use of tipper lories had a higher cycle time than using pick-up truck, the new service technology (HCS pick-up truck). The higher the cycle time the lower the efficiency hence the HCS had superior efficiency to the tippers.

The previous service technology (tipper lorries) evacuated more solid waste load in a longer collection route distance, hence utilized longer net travel time, (t_{net} of 58.0 mins) than pick-up truck. Thus, for the same trips, haulage by tipper was 154% or 1.54 min longer than the upgraded service technology, therefore reducing efficiency in day's operation. One trip for pick-up truck was one container volume ($4m^3$) but one trip for tipper is a wagon load of $7m^3$, about 1¾ times the value of pick-up container in about 2.4 time the cycle time of a pick-up truck. Thus, the pick-up with more frequent net travel time gained in volume evacuation and area coverage in the sum.

3.3.2. Disposal Rate: At the completion of a cycle time for one trip by a pick-up, truck the tipper would hardly complete its first collection trip whereas at the end of a cycle time by a tipper, a pick-up truck would have made more than 2 trips (almost 2½ trips). For 1 trip of a tipper giving loading rate of $7m^3$, the equivalent loading rate for pickup trucks was $2^1/_2$ x $4m^3$ or $10m^3$, hence collecting more from its faster, more frequent dump trip time.

However, [11] emphasized that for drivers to head to dump only when the vehicle is completely full (as does the tipper lorry) is generally not the most efficient way to handle dump trips. Therefore the effect of technology upgrade on the efficiency of collection is assessed.

3.4 Technology upgrade impact on collection efficiency.

Efficiency was computed as [17]

$$E_f = \frac{Cycle\ time \times number\ of\ trips/day}{Total\ working\ hours/day} \quad (4)$$

$$= \quad t_{net} \text{ x } N_t/H \quad (5)$$

Where $N_t = (H - \text{time loss})/t_{net}$ (6)

Substituting (6) into (4), then efficiency in terms of time loss is

$$E_f = \frac{Total\ working\ Hour - Times\ loss}{Total\ working\ hours} \quad (7)$$

$$= 1 - \frac{T_L}{H} \quad (8)$$

Using H = 8 hours and time loss T_L = w from Table 5, the following efficiencies (Table 5) as affected by time loss were obtained.

Table 6: Collection Efficiencies Based on Time Loss and Cycle Time

Vehicle	Avg Time Loss T_L	Total available hours, Ho	Cycle time t_{net}		Efficiency %	
			Low	High	Low	High
046	2.00	6.00	15.55	21.11	60	75
053	2.00	6.00	22.23	24.05	63	77
060	1.95	6.05	15.38	23.90	59	76
072	2.00	6.00	14.06	17.03	61	75
Avg			16.94	21.52	61	76
04	2.8	5.20	31.85	82.03	-	65
05	3.76	4.24	44.47	76.54	-	53
Avg						59

Efficiencies of the time-based collection by vehicles are shown in Table 5, indicating low and high-efficiency vehicular performances. ANOVA test showed that the difference between average low efficiency of the pick-up trucks (61%) and the tipper lorries (59%) were significant at p = .05 Also, the high efficiency difference between the tippers (65%) and the trucks (76%) was also significant.

The comparison indicated that tipper lorries were a low efficiency, time-based technology performers in the municipal solid waste collection while the HCS trucks with container-lifting collection had the upgrade technology advantage of high efficiency performance.

3.5 Benefits of Technology Upgrade

1. Haul container system comparatively had performance and technology characteristics which upgraded its technology above those of that previous tipper lorry performance. It is a single unit vehicle with less human interaction unlike the tipper with much human interaction.

2. The containerization of generated wastes in the residential neighbourhoods and other localities [18] provided cleanliness by HCS in waste handling and sanitary container locations such that vermin, rats and unsolicited sorters were handicapped. Unlike the case of tipper collection where wastes were left on the floor for all pests to host and for leachate egress to damage the environment, causing unsightly and nauseating site, and making sorters to further liter the locality with sacs of recoverable which were left pending collection, because there was no technology for source- separation of recoverable as yet, such as separate recycling bins or collection vehicles, and schedules.

3. The use of community bins at a fixed point in a residential neighbourhood or other localities [18] by HCS made the residents or dwellers to feel detached and safe from the nuances of the generated waste. That also helped the new users in suburbanized rural-urban fringes to do away with the rural culture of littering wastes about or applying the traditional background waste heap which may create sources of pest to domestic residences. Also it created in them a sense of responsibility to environmental cleanliness as they imbibed the more decent culture of self-delivery of wastes to community bins away from their residences. Unlike the curbside dumping of the generated garbage for manual collection by scooping by the 2 or 3-man crew in tippers. Where the garbage were left uncollected for days as in the 1-day sanitation day, they turned unsightly and breeding vermin's, flies and rats and other pests as well as leachate that degraded the in-situ soil or concrete pavement with its chemicals, as happened at waste dumpsite.

4. The crews In HCS the crew were the driver and at most one aide, unlike the 2 or 3-man crew in addition to the driver in the case of tipper Lorries. The cost implication on daily basis was higher on per head basis in tipper lorries operation.

5. The dump-trip time in the HCS was faster, hence making more frequent dumps in a day which optimized routes in the expanding urban metropolis [11]. Frequency of collection is an important aspect of municipal solid waste collection readily under a municipality control [18]. It was easier to collect more waste load by frequent thrift set-out in a large container than with tipper which rate of collection was either less than or equal to the HCS truck. The efficiency of collection in the truck was higher than the tipper at 75%:65% or 1.2:1.

IV. CONCLUSION

Two vehicular technologies for collection of solid wastes in Uyo municipality were compared over 5 trips of collection in four route zones in terms of dump trip time (t_{net}), total net collection time, set-out, tones/day rate, crew, maneuverability of vehicle in the urban routes, containerization and sanitation of container location and efficiency of solid waste collection.

Dump trip time of HCS varied between a minimum average of 17 min and a maximum average of 24 min. The tipper average was 82 min maximum. The t_{net} (max) ratio of tipper to truck was 1:3.5 indicating that truck completed the load collection at a rate faster than the tipper at the ratio of 1:3.5 of the truck: tipper.

The efficiency of HCS was superior to the tippers and varied between a minimum average of 61% and a maximum average of 76%, a tipper-to-truck ratio of 1:1.2.

The technology of HCS had finer delivery characteristics which were addition to faster $\mathbf{t_{net}}$, finer delivery and higher efficiency and more effective waste collection where cleaner container location, fewer crew and better sanitation and aesthetics in residential neighbourhood and locality and is highly recommended for used in urban metropolis and suburbanized outskirts as Uyo urbanization and other municipalities expand.

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COMPETING INTEREST

We the authors declare that no competing interests exist. The work was carried out solely by us. We hereby invest on you the copyright for the publication of this paper.

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BIOGRAPHICAL NOTES

Dr.O. E. Essien received his B. Sc (agricultural Engineering) in 1978 and Ph.D (Agricultural Engineering) in 2004 from University of Ibadan. He is Assoc. Professor in the Department of Agricultural and Food Engineering, University of Uyo. He is a fellow of Nigerian Institution of Agricultural Engineers (NIAE). He has many publications in the area of Environmental water quality, soil and water conservation engineering, amongst others. He designed and supervised the research study and wrote the article.

O. C. Nnawuihe is agricultural Engineer, University of Uyo, Uyo. He carried out data collection along with others in the field.